WIND FARM SAFETY IN AUSTRALIA

This document has been prepared as a part of project made possible by a grant of monies from the Australian Greenhouse Office to the Australian Wind Energy Association under the Renewable Energy Industry Development Programme (Round 5).

This document is a detailed briefing paper discussing the issue of safety of wind farming in Australia. This paper was prepared as background information for the preparation of a fact sheet for dissemination to the general public. As a result this document, any related documents (listed below) and the fact sheet itself attempts to be as non-technical as possible and sometimes goes to great pains to explain what may appear to be quite obvious to someone intimately involved in either wind energy or specific environmental issues.

However, as is often the case, such attempts may unintentionally oversimplify the issue or present information in a distorted way. We may also have made errors or omissions in the preparation of this document. Please do not hesitate to forward any suggested changes or additions to this document to Grant Flynn at Sustainable Energy Australia (Grant@SustainableEnergyAustralia.com.au).

Where possible footnotes have been provided within the text to allow the reader to consult the source article directly.

This document should be read in conjunction with the following sub-documents;

- None

This document has also been distilled into a very brief fact sheet of just 2 pages which can also be downloaded from the AusWEA: Australian Wind Energy Association web site at www.auswea.com.au.

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Sources of Information

- Saint Mary's College Indiana USA (Building a Wind Farm)
  www.stmarys.edu
- Royal Australian Air Force Aeronautical Information Service (AIS)
  http://www.raafais.gov.au/
- Civil Aviation Safety Authority (CASA)
  http://www.casa.gov.au/
- Air Services Australia
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- USA Department of Energy (DOE) Wind Energy Program
  http://www.eere.energy.gov/wind/faqs.html
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Air Traffic

There are various forms of air traffic and the reader is probably familiar with many of them. They include (but are not limited to);

- Commercial air operations
  - Commercial passenger transport services
  - Commercial cargo transport services
  - Charter transport services
  - Tourism air traffic
  - Agricultural Operations including; Crop dusting, spotting and mustering
- Private or Recreational air traffic
  - Gliding aircraft
  - Hot air balloons
  - Hand-gliders
  - Micro-light aircraft
  - Model airplanes
  - Kites
  - Parachutes
- Specialist Air Operations
  - Emergency services air traffic
  - Military air traffic
  - Space flights

Commercial air operations generally describes air craft operating between prescribed aerodromes, on prescribed flight paths and often in accordance with pre-determined schedules for the transport of passengers and/or cargo on a fee paying basis. The aircraft used in such operations vary from large, long range passenger jets able to carry several hundred people down to relatively small propeller driven aircraft that may carry only a few passengers at a time. In the case of charter transport neither the schedule nor the flight paths are fixed but will vary from charter to charter.

The management and area of operation of aircraft engaged in commercial transport is heavily regulated and strict protocols must be adhered to.

Private and Recreational Air Travel involves a variety of air craft operating in a seemingly random way. Recreational air travel is no where near as heavily regulated as commercial transport.

Specialist Air Travel by contrast is quite heavily regulated, and involves specialist aircraft and highly trained pilots. However the nature of operations means that these air craft will operate in unusual areas and in unusual circumstances.

The specific rules that govern the way an aircraft may operate are quite complex and will depend upon;

- the type of aircraft (balloon, passenger jet, helicopter, glider, etc),
- the type of operation for which the aircraft is being used (private use, aerobatics, commercial transport, search and rescue, etc),
- the qualifications of the pilot (Visual Flights, night rating, instrument rating, etc),
- the area in which the flight will take place (around an aerodrome, across water, open country, etc) and
- the time and conditions during the flight (day, night, good visibility, storms, etc).

However in the context of safety of aircraft operations in the vicinity of a wind farm site they are generally the same.

OPERATIONS IN THE VICINITY OF AERODROMES

The operation of air craft in the vicinity of an aerodrome is closely controlled – regardless of the nature of operation. This stands to reason given that there will be a heavy concentration of air movements in the vicinity of an aerodrome and aircraft will, by necessity, need to fly at low altitudes as a part of takeoff, landing and circling manoeuvres.

The control of aircraft around an aerodrome will depend mainly on the primary purpose of the aerodrome, the aircraft that use it and the services that can be financially justified at each aerodrome. Because wind farms are generally located in rural or remote areas, this paper will not discuss the operation of large commercial aerodromes (e.g. Tullamarine, Kingsford Smith, etc).

Generally, rural aerodromes will have no air traffic control (ATC) or instrument landing system (ILS) and aircraft separation is achieved by using a Common Traffic Advisory Frequency (CTAF) and on a see and be seen basis.

The aerodrome will typically be equipped with a Non-Directional Beacon (NDB) and have an approved non-precision approach procedure using either the NDB or Global Positioning System (GPS).

This is especially likely to be the case if the airport has a Regular Public Transport (RPT) air service. Aeroplane Landing Areas (ALA), especially unlicensed ones, will have none of these services and will rely on the familiarity of the pilot with the ALA.

The approach procedures for an aerodrome are designed by CASA and issued by Air Services Australia. The procedures are designed to cater for a range of aircraft of varying speeds. The procedures are quite specific in that they specify headings and minimum altitudes at various locations.

In general terms the procedures are designed to provide guidance to a pilot to enable him or her to descend in cloud and manoeuvre the aircraft to an appropriate point where visual contact with the aerodrome can be made. The procedure specifies a minimum safe height at which the pilot must have visual contact with the airfield prior to continuing the approach. If visual contact is not made, a missed approach procedure must be carried out.

Where instrumented landing systems are not available a Non-Precision Approach procedure is designed to position a pilot to a point where a visual approach to the runway or the circuit area can be under taken. A Non-Precision Approach is conducted where visibility is low.

Incoming aircraft make approaches to the aerodrome using a non directional beacon (NDB) or global positioning system (GPS) until they achieve visual contact with the ground. Pilots will then use the published approach paths and procedures – which exist for all aerodromes – to land their aircraft safely. Importantly these approach paths and procedures allow a pilot that may not be familiar with the area to operate their aircraft safely.

For each approach a Minimum Descent Altitude is nominated, at this point, if the pilot is not in visual contact with the field a missed approach MUST be executed.

The procedures define minimum descent altitudes at which a pilot must have visual contact with the runway. A ‘missed approach point’ is defined so that if a pilot is unable to achieve visual contact with the runway by this point the pilot must navigate the aircraft along a defined missed approach path. The missed approach path is a specifically defined route which provides sufficient terrain and obstacle clearance (remember the pilot is operating with limited visibility). If visual contact cannot be made by the time the pilot reaches the missed approach point, a pilot may circle the aerodrome along the missed approach path and make further landing attempts.

However if visual contact cannot be made after repeated attempts, the only approved response is to divert the flight to another airport.

The approach paths and procedures differ according to the size (weight) of the aircraft, divided into four categories (A to D). Smaller aircraft have lower minimum approach speeds and hence shorter defined approach paths. Faster and heavier aircraft may have longer and steeper approach paths.

Non Directional Beacon (NDB) Approach

The NDB approach is a non-precision approach, designed to position the pilot to a point where a visual approach to the runway or circuit area can be undertaken. The approach is designed to ensure safe heights above the surrounding terrain is achieved throughout the approach. The approach is also designed to achieve minimum descent altitudes at various points along the flight path.

When the pilot is at a point called the "Missed Approach Point" (MAPt) and visual contact with the runway is not achieved, the pilot must conduct a missed approach. A missed approach must be conducted by following the missed approach flight path, thus ensuring sufficient terrain clearance is maintained. Having conducted a missed approach, the pilot may elect to try again or proceed to an alternate airport.

Approaches are designed for the appropriate aircraft type category that could potentially use the airport. Category A aircraft include small single engine aircraft type while category D include high speed corporate jet type aircraft, where category A is the slowest and category D is the fastest.

GPS Approach

The GPS approach is another non-precision approach, designed to position the pilot to a point where a visual approach to the runway or circuit area can be undertaken. The GPS approaches for a typical rural airport are straight in approaches on an extended runway centreline. The aircraft is positioned some 10 nautical miles from the runway threshold, and then the pilot conducts a long final approach to the runway.

In this case a missed approach is conducted if visual contact with the runway has not been achieved by a particular minimum height (specified for each runway) or if horizontal visibility is less than a prescribed limit.

Again the missed approach will allow for circling of the aerodrome so that the approach can be re-attempted and if subsequent attempts also fail the pilot will need to divert to an alternative aerodrome.

Obstacle Limitation Surface (OLS) Charts

The OLS is a series of surfaces that set the height limits of objects around an airport. The objectives are as follows:

- Maintain obstacle free airspace around the airport
- Maintain safe aeroplane operations
- To limit the growth of obstacles around the aerodrome

The OLS is based on runway lengths and airport height and is published by Air Services Australia in the En Route Supplement Australia (ERSA).

The OLS defines the limit to which objects may project into the airspace. The surfaces may be at varying heights above the aerodrome depending upon where in the approach path or missed approach path the area is located.

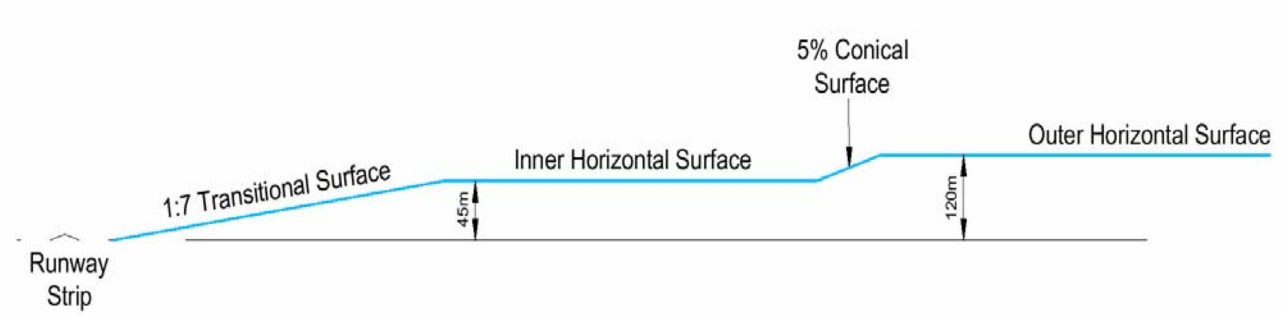


Figure 1 Sample of Obstacle Limitation Surfaces Around an Aerodrome

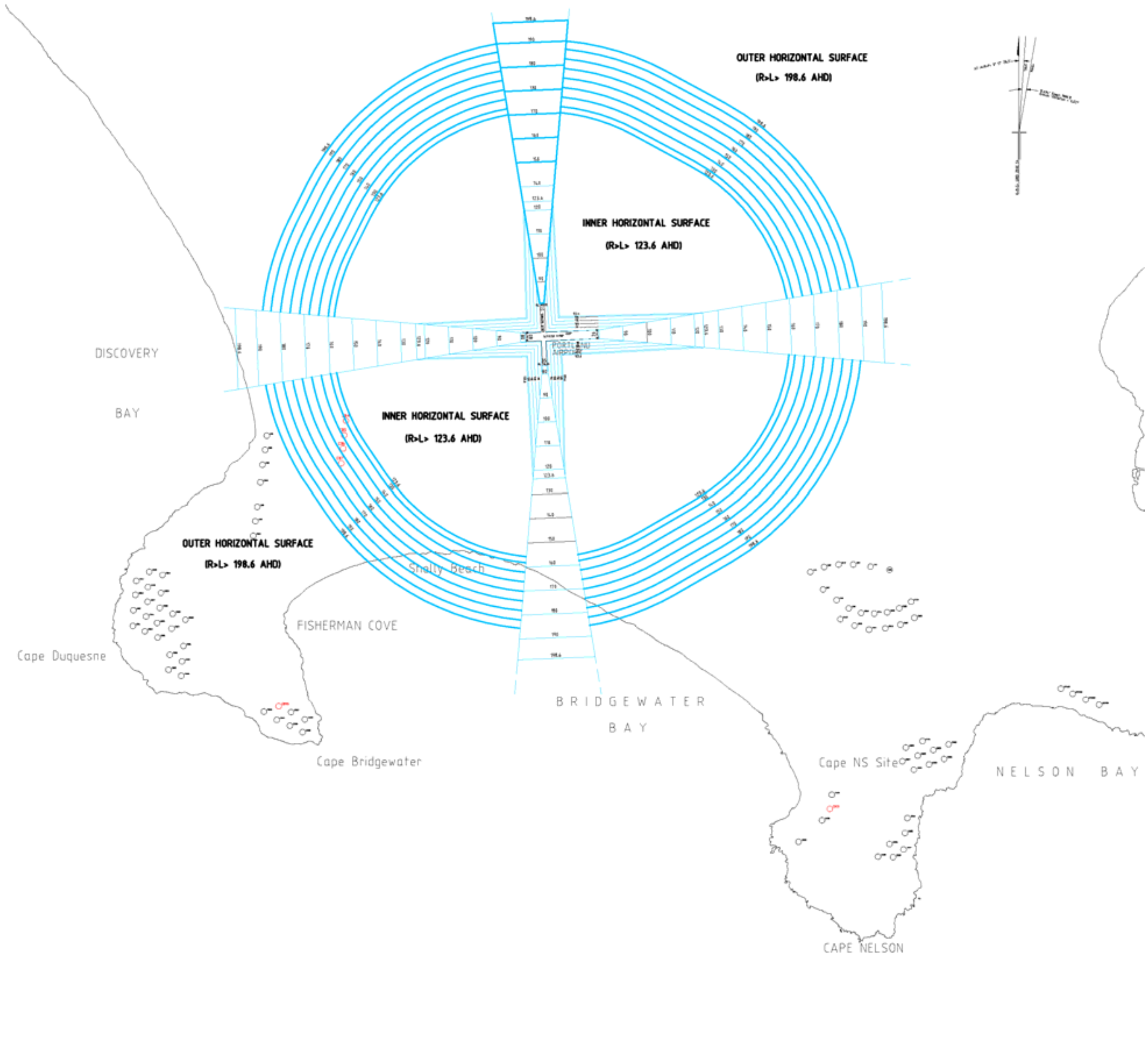


Figure 2 Approach Paths and OLS at Portland Airport, Victoria

Circling Minima

The circling minima, is the minimum altitude at which the aircraft can circle the airport in marginal weather. This minimum altitude applies to aircraft operating under Instrument Flight Rules (IFR). Along with the minimum altitude requirement, there is also a requirement for a minimum forward visibility.

After completing an instrument approach, a circling minima is required so the pilot can manoeuvre the aircraft above the airfield and surrounding area in order to either view the wind sock to determine wind direction and strength or position the aircraft for landing.

The circling heights are calculated on the surrounding terrain and obstacles in a given area.

Circuit Heights Around Aerodromes

By convention, the following circuit heights are flown unless otherwise specified;

- Jets - 1,500 feet above ground level;
- Piston/turbo prop - 1000 feet above ground level; and
- Helicopters - 800 feet above ground level.

Operations Away from Airports

Piloting an aircraft requires specialist training and, by and large, enthusiasts will take their personal safety, safety of their own aircraft and the safety of other aircraft very seriously.

Typically, private and recreational aircraft are operated by pilots operating under Visual Flight Rules (VFR). A VFR flight may only be conducted:

- In Visual Meteorological Conditions (VMC)
- Provided that, when operating at or below 2,000 feet above the ground or water, the pilot is able to navigate by visual reference to the ground or water;
- At sub-sonic speeds

The Civil Aviation Rule (CAR) 157 relates to height limits for flying of aircraft. In general terms an aircraft must not fly over:

- any city, town or populous area, at a height lower than 1000 feet; or
- any other area at a height lower than 500 feet.

A height specified in the above rule is the height above the highest point of the terrain, and any object on it. This height extends from a point on the terrain vertically below the aircraft out to a radius of 600m from the object in the case of an aircraft other than a helicopter, or 300m in the case of a helicopter.

The above does not apply though, if:

- through stress of weather, or any other unavoidable cause, it is essential that a lower height be maintained; or
- the aircraft is engaged in private operations or aerial work operations, being operations that require low flying, and the owner or operator of the aircraft has received from CASA either a general permit for all flights or a specific permit for the particular flight to be made at a lower height while engaged in such operations; or
- the pilot of the aircraft is engaged in flying training and flies over a part of a flying training area in respect of which low flying is authorized by CASA under CAR 141(1) (Low Flying Training Areas); or
- the pilot of the aircraft is engaged in a baulked approach procedure, or the practice of such procedure under the supervision of a flight instructor or a check pilot; or

- the aircraft is flying in the course of actually taking-off or landing at an aerodrome; or
- the pilot of the aircraft is engaged in:
  - a search; or
  - a rescue; or
  - dropping supplies in a search and rescue operation; or
  - the aircraft is a helicopter:
    - operated by, or for the purposes of, the Australian Federal Police or the police force of a State or Territory; and
    - engaged in law enforcement operations;
- or the pilot of the aircraft is engaged in an operation which requires the dropping of packages or other articles or substances in accordance with directions issued by CASA.

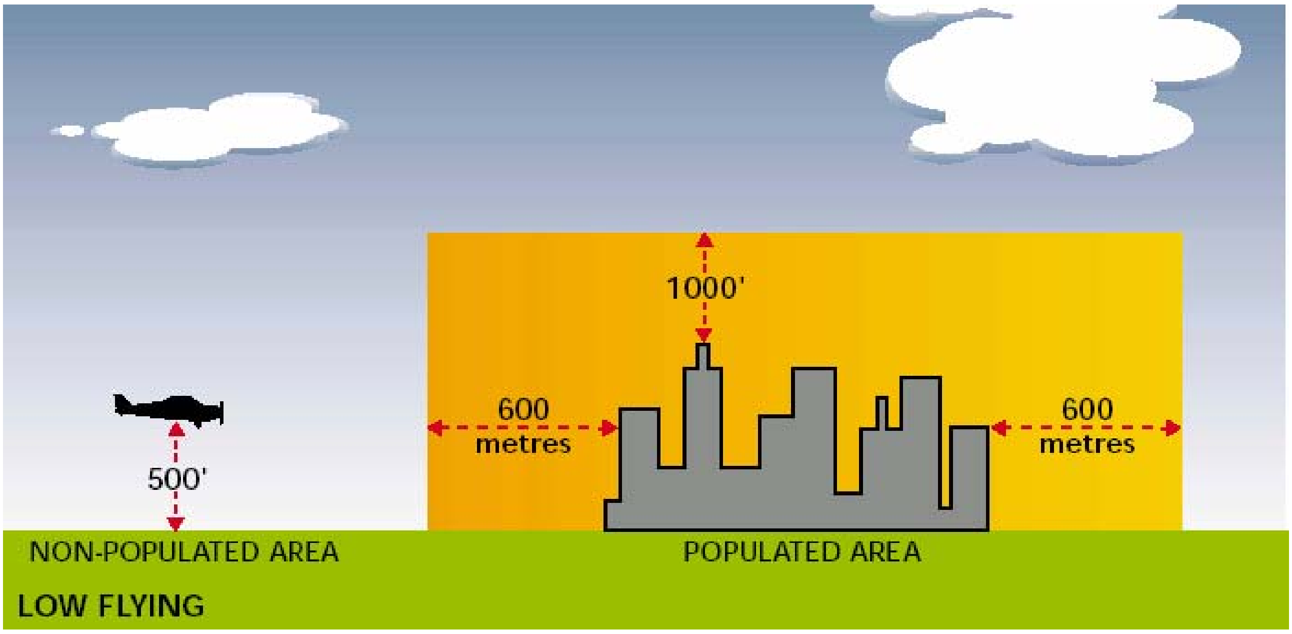


Figure 3 Diagram Showing Minimum Flying Heights Away From Airports

From the above it is clear that the minimum height at which an aircraft operates outside of the prescribed area of an aerodrome (500 feet or 152 metres above ground level) is well above the blade tip zenith of any wind turbine generator *operating* in Australia so far. Furthermore, no wind turbine generator has been *proposed* for use in Australia where the blade tip zenith would be above this height.

ANTI-COLLISION MARKING AND LIGHTING OF OBSTACLES

Regardless of whether an obstacle is near an airport or not, CASA must be notified of any structure within Australia and its territories that projects more than 110 metres above ground level. CASA will then make an evaluation as to whether anti-collision lighting or an aviation safety colour scheme is required for the safety of aircraft operations.

The anti-collision lighting traditionally involves the installation of strobe lights on top of a structure that shine up and out to warn pilots of the presence of the obstacle. Colour schemes generally involve the painting of the obstacle with alternate bands of pure white and signal red.

CASA's Manual of Standards (MOS) part 139 requires that the obstruction lighting be mounted at the top of the structure. However proposed changes to the MOS will mean that this requirement will be relaxed to allow wind turbine generators to mount obstacle warning lights on top of the nacelle, bringing them in line with international practice.[1]

Clearly for reasons of visual amenity and landscape impacts, it is highly undesirable for wind turbines to require either night safety lighting or aviation safety colour schemes.

Australia's Best Practice Guide indicates that wind farm developers should contact CASA as a matter of course, regardless of where the proposed wind farm is located. There may be specific reasons why a wind turbine generator may be required to have obstruction lighting or aviation safety colour schemes. For example such treatments may be required where a wind farm is proposed in a mountainous area where light aircraft may reasonably be expected to operate. Such light aircraft may be limited in their ability to remain at the appropriate altitude above ground level in such areas.

Of course consideration needs to be made of the specific operational characteristics of specialist aircraft such as military, police and rescue aircraft. This is discussed below.

IDENTIFICATION OF OBSTACLES FOR SPECIALIST OPERATIONS

Specialist air craft operations may involve the operation of an aircraft below the typical 500 feet above ground level limit. In the RAAF the F-111 (otherwise affectionately referred to as the "pig") is a long-range strike & reconnaissance aircraft. This aircraft is capable of flying at extremely high speeds at low altitudes in order to prevent RADAR detection.

Generally the RAAF uses the terms "medium altitude" to mean 2,000 – 25,000 feet above ground level, the term "low altitude" to mean from 500 – 2,000 feet above ground level and the term "low altitude-high speed operations" may involve operation below 500 feet and at speeds in excess of Mach.

The Royal Australian Air Force Aeronautical Information Service (RAAF AIS) is responsible for the provision of a variety of aeronautical services. One such service is the Tactical Pilotage Chart (TPC). The TPC is designed to provide an intermediate scale translation of cultural and terrain features for pilots/navigators flying at very low altitudes (below 500 feet above ground level) through to medium altitudes or low altitude-high speed operations.

Complete coverage of the Australian area of influence needs to be available because military aircraft (RAN, ARA and RAAF) and other specialist air operations (e.g. Police and Air Ambulance) will potentially need to operate in any part of Australia and may need to operate in less than ideal conditions.

In this regard any potential obstacle more than approximately 15 to 20 metres above ground level should be reported to the RAAF AIS. As far as the wind energy industry is concerned this will involve wind monitoring masts used during development phase of a wind farm as well as the wind farm itself. Such reports can be made very easily and online via the RAAF AIS Vertical Obstruction Report Form. (follow links to "Products" then "Vertical Obstruction Report Form")

WIND TURBINE NACELLE AND BLADE TIP WARNING LIGHTING

Wind energy plants with blade tip heights over 110 m may need to be equipped with a flight aircraft warning light. Usually this is solved by means of red indicator on top of the nacelle cover. So far this has not been necessary in Australia however many examples can be found in other parts of the world.

[1] Review of this section of the MOS is currently under review and readers are advised to contact CASA for full details

In March 2003 several Nordex turbines installed in two locations near Uckermark, Brandenburg, in a project worth around EUR 22.6 million. Each of the S77 model turbines has a nominal output of 1,500 kilowatts. To ensure that this output is achieved in the medium wind conditions of the site, the turbines are fitted with a large rotor with a diameter of 77 meters (compared to normal 64m) mounted on towers with a height of 100 meters (compared to normal 65m).

The very high blade tip zenith (138 metres above ground level) means that the turbines must be fitted with flight safety illumination. For the first time these Nordex turbines featured the “EST 10” obstruction light, which Enertrag has developed in conjunction with rotor blade producer N.O.I..

Unlike most hazard beacons, which are fitted to the nacelle, this obstruction light is integrated in the tips of the rotor blades and is activated whenever the blade moves across the top 120 degrees of the sweep. By locating the beacons in the tips, the highest point of the obstacle is marked.

The advantage of this solution, which has been approved by the German Ministry of Transport, is that the light intensity required is roughly 160 times weaker than with conventional solutions and is thus less of a distraction to local inhabitants and animal life in the proximity of the wind farm. Maintenance is made easier by locating all the electrical lighting control units within the hub.

The use of blade tip lighting has not been proposed in Australia yet (in fact no turbines have required any lighting or aviation marking so far). It is still unclear if the rotation of blade tip lights will impose any particular problems. Consequently the wind turbines described above will be followed closely by aviation safety authorities around the world.

Impact of Wind Farms on Safe Operations near Aerodromes

The height of wind turbine generator towers and blades mean that if there is an airport in the vicinity, flight path envelopes will need to be avoided. The Civil Aviation Safety Authority (CASA) will also need to be consulted about the need for warning lights on the wind turbine generators. Reasonable separation from airports is the preferred approach.

The key aviation issues to be addressed for most rural aerodromes relate to the compatibility of the wind farm with the following airport operational issues, as prescribed by CASA:

- The Obstacle Limitation Surfaces (OLS) of the airport
- The Non Precision Approach procedures:
    - Non-Directional Beacon (NDB) Approach
    - Global Positioning System (GPS) Approach
    - Circling Minima

The assessment criteria for aviation safety is typically based on the intrusion of any structures associated with the wind farm into the safe flying envelope around the aerodrome in question, as prescribed by CASA.

Obstacle Limitation Surface

The objective of the OLS is to define an airspace area around the airport that will be obstacle free so as to permit the intended aircraft operations in a safe manner. This is achieved by establishing a series of obstacle limitation surfaces that define the limits to which objects may project into the airspace.

The height of each of the wind turbine generator tower will need to be individually reviewed to check if any part of the machine will protrude through the OLS surface.

Obstacles that penetrate the OLS may in certain circumstances cause an increase in the obstacle clearance altitude/height for instrument approach procedures or associated visual circling areas. All obstacles that penetrate the surface must be reported to CASA.

Approach Paths and Circling Minima

The Circling Minima is the minimum altitude at which the aircraft can circle the airport in marginal weather. Approach flight paths provide safe operational areas to allow a pilot to manoeuvre the aircraft safely to a position from which the aircraft can be landed.

As with the OLS, the height of the approach path and circling minim need to be identified in order to check whether the proposed wind generator towers would protrude into them. Regardless, any obstacle may have an effect on visual and instrument approaches and the circling minima and missed approached heights in marginal weather.

The NDB approach flight paths need to be reviewed for all categories of aircraft relevant to aerodrome. The minimum clearance between the flight path and any obstacle is identified, based on the published NDB approach procedures.

Approach procedures are designed around existing terrain and obstacles. Depending on the height and location of any new obstacles, the procedure may need to be reviewed and depending on the impact may require a redesign. However in most cases it will be the wind farm layout that will need to be reviewed (in accordance with best practice guidelines).

The regulations require a pilot to allow for wind effect and compensate accordingly. It is however reasonable to assume in any study of wind farm impact that an inexperienced pilot could be carrying out the approach with a wind of up to 30 knots blowing across track. It is important that obstacles do not penetrate into reasonably predictable variations from the circling minima, allowing for strong wind conditions and an inexperienced pilot making insufficient course correction on an approach. This could be considered as a worst case scenario for the evaluation of the impact of any proposed wind turbine generators. If no allowance is made for wind correction by the pilot, then the off track flight path should allow for wind and the 5-degree track error.

It is possible to increase the circling height to avoid obstacles associated with a wind farm. However, by increasing the minimum height, the airport risks a higher number of missed approaches under poor weather conditions due to the increased possibility of the aircraft still being in cloud when they reach the MAPt. Any increase in minimum circling height should be reviewed with available cloud base data and in consultation with the aircraft operators.

There is also an option to reduce a sector(s) of the circling area and have this noted as “No Circling”. Many airports already have a ‘No Circling’ area in a particular quadrant. However any additional ‘No Circling’ areas may have an operational restriction that could effect aircraft operations. This would need to be evaluated by CASA.

Aircraft Landing Areas (ALA)

Aircraft Landing Areas in rural areas are usually not protected by any designation or Civil Aviation requirements. If there are ALA in the vicinity, the wind farm developer will need to consult with owners and users to ensure that potential adverse effects are avoided or mitigated.

Impact of Wind Farms on the Safety of Commercial Air Transport

Wind farms are unlikely to impact on the safety of commercial air transport beyond the potential impact on the operations of aerodromes (discussed previously). Commercial air transport operations are strictly regulated and aircraft operate at altitudes well above the height of wind turbine generator blade zeniths.

Impact of Wind Farms on the Safety of Recreational Aircraft

The operation of recreational aircraft is less predictable than that of commercial aircraft. Furthermore, the array of instruments carried aboard these aircraft is typically less extensive and the instruments may be less sophisticated than those used in commercial air transport aircraft. It may also be the case that the pilot is not as experienced as those in commercial air transport. As a result recreational pilots will generally operate their aircraft within proximity of their own aerodrome (though this is not always the case).

Strictly speaking a wind farm should have no impact on the safety of recreational aircraft operations beyond the potential impact on aerodrome operations (discussed previously). Outside of aerodrome areas, recreational aircraft should not fly low enough to come into contact with wind turbine generators.

It could be argued that a wind farm may have an impact on the safety of an aircraft operating outside of the prescribed regulations (i.e. below the floor limit of 500 feet above ground level). However it can reasonably assumed that a pilot would not be so reckless as to do so, except in an area with which he is extremely familiar or in the most exceptional emergency circumstances. It would be unreasonable to preclude any structure just in case a pilot might fly below the prescribed limit.

Impact of Wind Farms on the Safety of Crop Dusting

Agricultural aviation is undertaken for the delivery of the following types of items;

- Liquids.............Fungicide, Herbicide and Insecticide application to crops
- Solids ....Granular Fertilisers application to pasture and crops
- Baiting ....Oats, Carrots, etc for control of rabbits, etc
- Dispersants ......Oil Spills
- Retardants ....Fire Bombing during bushfire control operations

Aircraft play an important role in crop protection for:

- **Cotton** - aircraft are an integrated part of cotton farming, ensuring crops are protected throughout the season.
- **Rice -** almost all the Australian rice crop is sown by air and then protected by aircraft throughout the season.
- **Bananas -** aircraft contribute to the black sigatoka eradication program.
- **Cane -** cane is too high for anything other than treatment by aircraft.
- **Conservation farming -** aircraft avoid soil compaction. Broad-acre-aircraft provide quick coverage when it is needed on large areas.
- **Topdressing -** many pastures for sheep and cattle are inaccessible for anything except aircraft.
- **Fruit and vegetables -** aircraft help growers to ensure top quality food for the table.
- **Potatoes -** aircraft deliver sprays to kill insects and fungus that could damage crops.
- **Emergency assistance -** during emergencies, the availability of agricultural aircraft for fire bombing and plague locust control relies on the maintenance of a viable agricultural aircraft industry.

Agricultural pilots undertake many hours of specialist training before they achieve the Ag Rating. Agricultural aviation in Australia has a better safety record in operation than that recorded for private flying, general aviation and helicopter operations. Given the many hours of utilisation of agricultural aircraft on low level operations (well below the normal 500 feet above ground level limits), this safety record of 3.6 accidents per 10,000 flown hours illustrates the professionalism of the industry as a whole.

Agricultural aviation operators have been utilising satellite images and processing systems (e.g. BASI INDICATE) for job planning and spray treatment area mapping for some years. This modern technology has provided "real" information to pilots, offering visual presentation of what the pilot will see when he gets to the job, an eagle eye view of the surrounding region and neighbouring farms or residences plus accurate reproduction of the areas to be sprayed.

From statistical data prior to the summer of 2000 approximately 44% of Gwydir Air's incidents resulted from power line collisions. During the summer of 2000, Gwydir Air[2] was able to source the power line grid software from its local electricity supplier North Power as a trial program. By overlaying the power line maps over the satellite maps that are generated for the spray program, powerlines can be projected as they exist in the field, with the added bonus that where they "end" is a residence.

Normal precautions and job planning still prevail but the new mapping capability provides a graphic visual environment for pilots to work in. Safety in agricultural aviation starts with thorough job planning and visual inspections but when added to this modern approach, avoidance of many incidents or accidents is possible over the years to come.

Agricultural aviation is more likely where steep terrain makes land-based delivery of fertilisers or biocides less cost effective. However, even in areas without steep terrain agricultural aviation operations may be undertaken so as to avoid the physical damage to crops caused by land-based delivery systems.

Before an agricultural aviation operation is undertaken the operator's Operations Manager will need particular information in order for the job to be completed timely, safely and effectively:

- Total Area to be treated.
- Crop or target type.
- Reason for treatment.
- Growth stage of weed or pest.
- Recommended treatment agent.
- Susceptible crops, houses, waterways, etc in vicinity of target.
- Preferred wind direction
- Map reference.
- Airstrip availability and suitability.
- Water availability.
- Pilot safety issues - powerlines, etc.

In conjunction with the above, it is typical requirement for an Aerial Application Request Form to be completed, signed and forwarded to the operator prior to work commencing.

[2] for more information regarding the integration of satellite imagery and the new grid program contact Guy Hovenden, Ag Services Manager Gwydir Air - Email: guy@gwydir.com.au, tel 02 67 511499

In most cases the restriction on crop dusting operations (if any) in the vicinity of the wind farm will be limited to the land which is hosting the wind farm. The remuneration obtained from the wind farm may therefore need to be assessed in view of any potential restriction to operations.

Impact of Wind Farms on the Safety of Parachuting

Parachuting is a dangerous sport and enthusiasts take their own personal safety and those of their fellows very seriously. Thorough planning is undertaken to maximise the safety of each and ever parachute jump.

Recreational parachuting is generally undertaken in close proximity to specific host aerodromes. The impact (if any) on the safety of recreational parachuting operations will generally limited to the impact on the aerodrome itself. Wind farms clearly should not be located near the parachutists' "drop zone". Given that the drop zone is often in very close proximity to the aerodrome this is unlikely to be a problem.

Demonstration and military parachuting are unlikely to have their drop zone close to an aerodrome. However significant work is done by the responsible parachuting organisation to ensure that obstacles such as wind turbines are avoided when selecting their drop zone.

From the above it is considered unlikely that wind farms will have any impact on the safety of parachuting.

Impact of Wind Farms on the Safety of Tourism Flights

Tourist aircraft and hot air balloon operations are generally conducted over relatively short flight lengths and in a limited area in close proximity to the aerodrome or aircraft landing area from which the flights operate (though this is not always the case). Unless specific exemption is provided by CASA such flights are still bound by Visual Flight Rules or Instrumented Flight Rules both of which require the flight to keep more than 500 feet above ground level. This is well above any proposed wind turbine generator blade tip zenith heights in Australia.

During the planning process a wind farm developer should make every endeavour to identify any ALA that is used by tourism aircraft and treat the operator as a stakeholder in the development process. This will help ensure that the needs and aspirations of the operator can be appropriately dealt with in the development of the wind farm proposal.

Once in operation a tourist flight operator or balloon pilot should be well aware of the existence of the wind farm and so will be able to take this into account in the preparation of flight plans.

Impact of Wind Farms on the Safety of Hand Gliders and Micro-Light Aircraft

The operation of aircraft such as hand gliders, micro-light aircraft and model aeroplanes are extremely variable. Where it is reasonable to expect operation of such aircraft in the vicinity of a proposed wind farm site (e.g. hand gliding club launch points or wind farm neighbour a micro-light enthusiast) it will be important to add such groups to the list of stakeholders that need to be consulted during the planning process.

For the most part such activities will only be impacted if it is conducted on or immediately adjacent to the land upon which the wind farm is proposed. As a consequence such activities will require the permission of the landholder who will host the wind farm. It is important that potential impacts are carefully considered and expert advice is sought. It is too easy to dismiss such activities out of hand and such a response may not be necessary.

Once the wind farm is in operation it may be prudent for the wind farm operator to conduct information sessions with such groups to discuss the operation of a wind farm and the potential dangers of operating aircraft in proximity of the wind farm.

Impact of Wind Farms on Operation of Aviation RADAR[3]

Aviation RADAR systems operate around major airports and military airports. To date, no wind farm proposal in Australia has been suggested for a location where it would have an impact on aviation RADAR systems. This section is included to ensure wind farm developers are aware of the potential impact and also to generally describe potential problems that are being faced in other parts of the world.

Principles of RADAR

Fundamentally a simple RADAR sensor consists of a radio frequency transmitter, a directional antenna and a receiver followed by a processor and a display. The RADAR transmits a pulse of ultra-shortwave electromagnetic energy via the antenna in a known direction. When this pulse of electromagnetic energy strikes an object a proportion of the energy is reflected back as a signal to the RADAR's receiving antenna. This return signal is then amplified and, after signal processing, displayed as a RADAR picture. The range to a reflecting object is determined on the measured time between the energy leaving the RADAR and the reflected energy being received.

The received signal at the RADAR contains reflections from many objects, both moving and stationary. Reflected signals from stationary objects such as trees, the ground and even wind turbine towers are collectively termed clutter. Most modern RADARs are designed to differentiate between clutter and moving objects (such as aircraft) based on the Doppler Effect.

However there are many effects that conspire to reduce the performance of the system including distortion of the received signal. RADARs are susceptible to distortion when it receives high level return signals that exceed the limits of the RADAR's design from large and highly reflective objects.

Types of RADAR

Aviation RADAR has four main uses;

- **En-Route Surveillance RADAR** - surveillance of aircraft as they are en-route between airports
- **Terminal Manoeuvring Area RADAR** – for management of aircraft within the airspace of an airport as they are leaving or arriving
- **Airport Surface Detection Equipment** – For the management of aircraft while on the ground and detection of airport intrusions
- **Precision Approach RADAR** – used when an aircraft is landing with the help of the air traffic controller – i.e. 'talking down' the aircraft pilot. This is also referred to as Ground Controlled Approach.

Additionally there are commonly used landing aids that rely on the transmission of radio frequency beams from ground equipment and "beacon" systems such as VOR. The precision of the beams used in landing systems is of paramount importance to aircraft safety. Two landing systems that are in use are the Microwave Landing System (MLS) and the Instrumented Landing System (ILS).

Extent of Wind Turbine Effects on RADAR Signals

No two RADAR installations are alike since the operational settings for the RADAR are customised to the local requirements. The various effects of a nearby wind farm on any

[3] Feasibility of Mitigating the Effects of Windfarms on Primary Radar

particular Air Traffic Control or defence RADAR will be unique to each system. These effects have been classified into two groups:

- Signal distortion within the RADAR signal processing, causing loss of performance.
- Detection of erroneous signals producing output to the RADAR display

Signal distortion is caused by the very large RADAR cross sections of wind turbines. Modelling and actual assessment of RADAR installations affected by turbines indicate significant variability in the level of distortion between RADAR sites and across operating conditions. Many RADAR installations may not suffer degradation at all.

The wind turbine can be considered as consisting of three major elements; the tower, nacelle and blade assembly. It is important to note that wind turbines, not only because of their physical size, but also because of the shapes and materials used, are significantly different to buildings and other structures such as electricity pylons, large chimneys, etc.

Details of the construction of a wind turbine generator are important in assessing the potential impact on nearby RADAR systems as seemingly minor components may generate significant variations in the RADAR characteristics of the machine. As an example, the construction and shape of the meteorological instrument cluster on top of a turbine can resemble a corner reflector and be an efficient RADAR reflector that could produce a significant RADAR return even though it is not physically large (an effect that is exploited for instance in the "corner reflectors" fitted to small boats and to radio-sonde balloons). Small features such as ladders, brackets, doorways and anemometers will produce disproportionate reflected signals compared with their physical size. This is because of the reflecting and re-radiating mechanisms that take place.

TOWER REFLECTIONS

Though any part of the wind turbine may cause problems, the metal towers can reflect a high proportion of the transmitted signal back to the RADAR. This large reflection can result in “amplitude limiting” of the return signals within the receiver or signal processing circuits.

This amplitude limiting can induce distortion and may result in a desensitisation of the RADAR and therefore reduced ability to detect aircraft in the vicinity of the reflecting tower. The operator of the RADAR will not be aware of desensitisation and missing aircraft responses and so it is not possible for RADAR operators to respond to the introduction of a wind farm in the region.

Modern wind turbine towers are tapered and as a result most of the signal is reflected back into the sky rather than back toward the RADAR receiver. However the bending of the tower under the influence of windage and differential heating from the sun can limit the benefit of the tapering.

ROTATING COMPONENT REFLECTIONS

The blades of a wind turbine present a smaller surface area than the tower. Furthermore the curvature of the blade surface is more complex and so reflections are "focussed" in dispersed directions relative to the blade surface. In most cases the reflected signal will be very weak but theoretically there may be a point at which the blades and the RADAR system will be at a point where the reflected signal is strong – causing “blade flash”. Blade flash would have a similar impact to that of the tower reflections though it would be short lived. The risk of this occurring is very low and can only be quantified on a case by case basis.

Another problem is caused by the fact that the turbine blades are moving. As a result they will impose a Doppler Effect on the reflected signal. Techniques currently used in most RADAR processing systems to distinguish between reflections from moving and stationary objects are unable to differentiate between the Doppler Effects imposed by moving turbine blades and Doppler Effects imposed by a moving aircraft. This will mean that the RADAR operator is presented with a confused picture that declares both aircraft and wind turbines as moving objects.

Any rotating parts within the nacelle (shafts, generator armatures, etc) may also be visible through the head housing if its cover is RADAR transparent (such as thin GRP). This may cause Doppler components to be generated. It is therefore better to enclose the nacelle in reflective material so that the RADAR signals can be controlled and managed by design.

In the context of wind turbines, it is only the blade rotation that causes significant velocity components. When observed from the RADAR at right angles to the axis of rotation the blade velocity can vary from zero at the root to a maximum at the tips. In this case the tip velocity can be typically 50 metres per second or in future designs maybe up to 80 metres per second. This velocity lies within the velocity band that ATC RADARs are designed to detect and pass to operators (aircraft speeds typically lie between a few tens of metres per second up to an extreme of several hundred m/s at cruise altitudes).

RADAR CHOPPING

The rotation of the blades can also cause a modulation or "chopping" of the RADAR cross section of objects behind the blade. Chopping occurs because the blades intermittently obscure the returns from other objects. The effects on RADAR are considered to be insignificant, as the spectral spreading from the chopping effect causing amplitude modulation will be low.

OVERCOMING THE PROBLEM

Only a proportion of RADARs may suffer from wind turbine problems although at present the ratio is unknown. Simply modifying the RADAR signal processing to blank the detection of turbines is considered unsatisfactory for meeting the overriding requirement to maintain air traffic safety in air traffic control RADAR and to meet the more stringent requirements of military RADAR.

Clearly there are three main ways in which we can overcome the problems;

- Modification of the wind turbine generator design
- Modification of the wind farm design
- Modification of the RADAR system design

WIND TURBINE GENERATOR DESIGN

There are key aspects of turbine design that can be modified to reduce the RADAR signature:

- Shape of tower – the surface shapes and angles can be arranged to divert reflected energy away from the direction of the RADAR.
- Shape and materials of the nacelle – making the nacelle covers from reflective material will shield the complex internal structures. Then shaping covers to divert the reflections will reduce the impact on ground RADAR.
- Surface treatments – a range of RADAR absorbent materials are available that can produce some reduction in RADAR cross section. The effectiveness of these materials is limited but they could be used to overcome specific problems on individual sites.

Treatment of the blades will be limited by the need to maintain aerodynamically efficient shapes and surfaces. In the long term the reflective characteristics the blades may be determined by the build-up of contaminants, especially salts, on the surfaces.

WIND FARM DESIGN

During each windfarm planning application the following aspects can be considered as they relate to the impact on the operation of aircraft RADAR:

- Geometric layout and location of the wind farm.
- Changes to the design of the turbines to reduce their "RADAR signatures"
- Changes to air traffic routes in the vicinity of wind farms
- Changes to the status of the affected airports
- Re-location of the affected RADAR
- Deployment of additional military RADAR to “fill in” the areas where coverage has been lost

RADAR DESIGN

Modification of the RADAR system itself may involve;

- Blanking of the affected area
- Fill in RADAR systems to cover the affected area

Techniques that rely on “blanking” of the RADAR output in the vicinity of the wind turbines will result in a loss of the ability to detect air-traffic in an area greater than that occupied by the windfarm itself as well as extending up to the maximum altitude of the RADAR coverage.

Should distortion of signals prove to be a problem, and if no other measures can be found to minimise the effects, then the necessary intrusive modifications to the RADAR will require detailed knowledge of the system designs and implementation.

Effects from detecting erroneous signals are significantly reduced by adding to the RADAR non-intrusively, a modern "plot filter" using the latest sophisticated algorithms.

Risk of Fire

A great deal of time and investment has gone into protecting wind turbine generators from the effects of lightning, and for good reason. In the past lightning has been a major nemesis of wind turbine generators. Fire, on the other hand, has not been such an important issue, in part because wind turbine generator fires are infrequent and partly because, up until now, the values involved in a wind turbine generator fire were relatively small.

With the advent of the megawatt class wind turbine generators, the monetary values exposed to a single fire, no matter how unlikely means that fire risk attracts much more attention that it did in the past.

The risk of fire at wind farms, or the risk of fire damage to wind turbine generators, is very low, as a result of:

- The height of wind turbine towers above the ground;
- The lack of vegetation around the base of the turbine towers;
- The fact that the high-voltage connections are underground;
- Access tracks act as firebreaks and provide good fire fighting access;
- Lightning protection devices are installed on every wind turbine; and
- Dedicated monitoring systems that detect temperature increases in the turbines and shut them down when the threshold temperature is reached.

However the height and remoteness of wind turbine generators also means that without fire suppression systems the only thing to stop a fire once it starts is usually the lack of anything left to burn. Consequently fire suppressions systems are becoming an increasingly important aspect of wind turbine safety design.

WHAT ARE THE FIRE RISKS OF OPERATING WIND FARMS

Wind turbines manufactured today incorporate the highest quality and safety standards, but the potential for a fire always exists when electronics and flammable oils and hydraulic fluids exist in the same enclosure.

The wind towers can, at times, be considered fire hazards, due to escaped sparks and flames. This only happens when turbine bearings wear out, crankcases run out of lubricant, cables are damaged during rotation, there are electrical shorts, or electrical arcing occurs in the transmission and distribution facilities.

Sophisticated condition monitoring systems utilised in modern wind turbine generators ensure that these circumstances do not occur. With normal maintenance and servicing practices in place, a wind farm will not impose an increased fire hazard to the host community.

Fires due to machine failure in modern turbines are extremely rare. Cases of fire damage to land neighbouring wind farms are practically nonexistent. According to a leading insurer of wind farms with 15 years of experience and over 12,000 insured turbines, 90% of these very infrequent fires are due to older turbine models. They have had only one case of third-party damage, which was limited to a fire on a large haystack[4].

Despite the low risk of fire it is important that operators and service personnel remain aware of the local fire risks and follow the procedures and protocols established for each site. These are usually an extension of the construction

[4] Curt Malloy, Wind Pro Insurance, Palm Springs, CA, June 2002

procedures and protocols (see below) and include basic common sense precautions, often taken for granted in rural areas, such as policing of cigarette butts and the carriage of fire fighting equipment and communications equipment in all vehicles, etc.

FIRE SUPPRESSION SYSTEMS

Fire protection for wind turbines has always presented a challenge: How to provide a cost effective fire protection solution for an application that is located 50 – 100 meters above the ground?

Automatic fire-suppression systems can be installed in wind turbine nacelles so that the nacelle is flooded with a suppressor vapour to quench fires.

Cost is a major concern to developers and manufacturers because of the slim margins wind development must work with. Adding more systems or components affect the bottom line and this is a problem. The addition of fire suppression systems for example (in contrast to fire and smoke detection systems) can add significant cost. Given the relatively low risk of a fire it may be judged that the cost is too high for the seemingly slim benefit.

In recent times though, low cost fire suppression systems have become available (e.g. Firetrace). In these systems flexible, narrow tubing that is susceptible to flame temperatures is used. The tubing is then pressurised with fire suppression gasses. When a fire occurs the tubing ruptures and releases the fire-suppression gas at the hottest part of the fire. Such systems are able to suppress a fire in seconds, minimizing damage.

The thin tubing enables it to be inserted into small, narrow spaces. No electricity required so it will work even in electrical failure. The extinguishing agent is site-specific and can be selected to minimize damage to the equipment it is protecting.

WHAT ARE THE FIRE RISKS OF CONSTRUCTING A WIND FARM

Fire is a risk that needs to be considered in any construction activity and the construction of a wind farm is no different. The risk may be higher if construction is undertaken during the summer period. Construction during the summer period is more likely given the positive safety implications of the longer days (longer periods of good light even after normal work hours), warmer weather (to ameliorate the problems of wind chill on site) and calm Autumn weather (for crane operations).

Dealing with these risks is relatively well understood and can be appropriately managed through construction occupational health and safety management plans. As an example the following may be considered as a part of such plans;

- No smoking on site except in prescribed areas
- All vehicles to carry emergency communications equipment
- All vehicles to carry fire extinguisher or fire fighting equipment
- All vehicles to keep to made tracks
- Vehicles with catalytic converters prohibited from site on high fire risk days
- Implementation of “hot work” permit systems

WHAT SPECIAL TRAINING DOES MY LOCAL FIRE FIGHTING SERVICE REQUIRE

Anyone with any experience in this regard is asked to contact Grant Flynn so this section of the paper can be updated.

WHAT EFFECT DOES A BUSH OR GRASS FIRE HAVE ON A WIND TURBINE?

The impact of a bush fire on a wind farm will be fairly limited. Wind farms are generally located in open areas (trees cause turbulence in the wind and reduce the commercial viability of the wind farm) and so the surrounding area is likely to be only grass, low scrub or heathland. This sort of vegetation acts as a natural fire break against bush fires, though clearly grass fires also have significant potential to cause damage.

While grass fires can burn very hot they move very quickly and are generally short lived at a given location. Consequently it is very unlikely that the fire would be sufficiently hot, or burn for a long enough period, for it to have any impact on the buried underground cables. Likewise the flames are unlikely to be large enough to cause any damage to the blades or nacelle of the wind turbine generator. Some superficial damage can be expected to be caused to the exterior of the wind turbine towers; however there would be no risk of structural heat damage to the tower.

The greatest risk is to the switchyard, control room and grid interconnection power line. Clearly physical damage to either of these components will cause a shutdown of the wind farm (e.g. if the grid fails due to collapsing poles or control room is left unprotected and burns down). Other problems can be caused by the intense heat of a bush fire, which can significantly reduce the electrical resistance of air and allow for inter-phase faults both on power lines and in switchyard equipment. The electrical protection equipment within the switchyard will trip the wind farm.

In any of the above cases, while the physical damage may be perceived as slight, significant costs can be incurred due to lost production while the wind farm is unable to export its electricity to the national grid.

Have there been any fires in WTG in Australia?

No wind turbine fires are known to the author. If anyone has details of any wind turbine fire they are asked to contact Grant Flynn so this part of the paper can be updated.

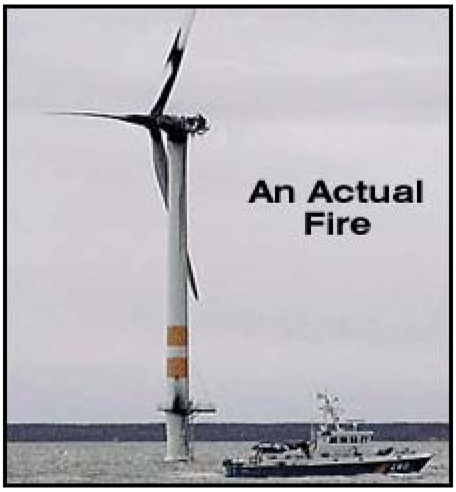
Case Studies of Wind Turbine Fires

The following case studies give some limited information about wind turbine fires experienced in other parts of the world.

Yttre Stengrund, Sweeden (year?)

The Yttre Stengrund fire is an excellent example of the dramatic capital loss a rare, “one-off” nacelle fire can now cause. The nacelle and rotor were completely destroyed by fire.

The off-shore location that meant the fire posed no threat to any third party also imposed a significant problem for combating the fire in a timely and effective way (see off-shore safety later in this document).



General Wind Farm Safety[5]

The wind energy industry enjoys an outstanding health & safety record. In over 20 years of generation with more than 100,000 machines installed worldwide, no member of the public has ever been injured during the normal operation of a wind farm[6].

A computer control system monitors the turbines all the time to make sure they are operating safely. Operators are able to “talk” to the control system remotely. If a fault were to develop, the particular turbine would automatically shut down and send an alarm to the maintenance engineer. In the event of a more serious fault the wind farm disconnects from the grid.

In very high winds the turbines stop automatically. There is also lightning protection to minimise damage to the machine from lightning strike. Vibration sensors prevent the turbines from working should unusual events occur, like the build up of ice or contaminants (e.g. insects) on the blades, etc.

A number of situations may be imagined, in which wind energy technology could affect the physical safety of human beings. In contrast to other energy sources, renewable resources “have practically no potential for severe accidents” that would endanger the public[7]”. The biggest risk associated with wind farms is that of an “attractive nuisance” to the extent they may attract trespassers who may subsequently injure themselves.

Even in the extremely rare event that anything comes off a wind turbine, the risk of injury from being hit within 210 metres of a wind turbine is comparable to the risk of dying from a lightning strike; beyond 210 metres, the risk is even lower[8]. Consequently the setbacks from residences due to noise constraints more than amply eliminate the risks to public safety.

“Wind turbines are no more dangerous to their owners, or to the public, than other sources of energy that course through our homes and workplaces every day. Natural gas, fuel oil and electricity all impose risk that we willingly accept. We also willingly accept the public risk imposed by our neighbours’ use of these technologies. The same standards should be applied to wind energy: nothing more, nothing less.[9]”

Most wind energy developments will not be on land available to the public, so public safety should not be an issue. However, this issue sometimes arises, for example if a public walkway coincides with a wind farm, or if the public are invited into the vicinity to view the working wind farm at close quarters.

May of the potential risks to the public are reduced or even eliminated by the use of enclosed tubular steel towers (rather than open lattice towers), locking systems on doors, intruder alarms, and protective safety fencing around open switchyards. All of the above are a part of best practice here in Australia.

Overseas, the construction period is found to have some risks for site workers. This is a matter for occupational health and safety (rather than for the development authority). Public safety during the construction phase also needs to be addressed. Because of the potential danger, particularly during erection of towers and blades,

[5] Wind Energy Comes of Age. Paul Gipe John Wiley & Sons1995 ISBN 0-471-10924-X. pp361-369
[6] British Wind Energy Association (www.bwea.com)
[7] Andrew F Frtitzsche, “The health Risk of Energy Production, “ Risk Analysis, 9:4,1989, pp565-577.
[8] Alexi Clarke, “Windfarm location and Environment Impact”, Open University, Milton Keynes England, June 1988 pp55-57
[9] Wind Energy Comes of Age. Paul Gipe John Wiley & Sons1995 ISBN 0-471-10924-X. pp363

the public need to be excluded from the immediate area. This may be done by temporary fencing. However, because tower erection is a very temporary process, usually taking less than a day, it may be acceptable for a contractor to have a person on site responsible for keeping the interested members of the public at a safe distance.

DESIGNED FOR SAFETY

The engineering design principle for wind turbines is safety throughout lifetime. Ensuring this requires not only a static calculation of the construction, but also a dynamic, aero-elastic calculation for the turbine under normal operational conditions as well as under various abnormal conditions (e.g. brake failure, etc.). For a horizontal axis turbine, the main fatigue-producing motions of the blades are the flapping modes (in and out of the plane of rotation) and the lead-lag modes (in the plane of rotation).

More difficult is the anticipation of failure modes caused by abnormal situations, since the details of such events can rarely be known in detail. As mentioned, a failure in the brake or control system may fall into this category, and also events caused by external factors, such as strikes by lightning, impact of various objects like birds, airplanes, etc. The approach here should be to minimize the risk of external failure causes, and to insist, e.g. by regulations, that the rotor is “fail-safe” under all conditions not involving external causes of unknown character. Extreme winds are of course part of the design basis, as are extreme lightning intensities for which ground-connected rods of sufficient current-carrying potential are incorporated in the tower and rotor blades.

With respect to the materials problems under the general heading “fatigue”, the balance of failsafe construction and economic penalty is improved by proper inspection techniques that acknowledge the occurrence of cracks but detect them and allow repair before they lead to failure.

Figure 4: Full Scale Testing of Blades for Fatiguing

Figure 5: Full Scale Test Facilities for Blade Testing

HEALTH HAZARDS FROM NOXIOUS SUBSTANCES

Few health effects are associated with the operation of wind turbines because it does not require use of toxic substances beyond lubrication oils and similar small scale usage of moderately harmful chemicals. The main risk of toxicity from chemical substances is likely to be associated with the construction phase through:

- use of epoxy resins and glues in blade manufacture e.g. glass fibre or laminated wooden materials,
- dust and chemicals introduced into the air during erection of concrete towers, and
- the health hazards associated with the manufacture of steel used in transmission and generator parts, as well as for tower and blades in some constructions.

Personal safety risk to workers can be easily managed through the use of well understood handling practices when dealing with these substances.

Unlike most other generation technologies, wind turbines do not use combustion to generate electricity and hence don't produce air emissions. The only potentially toxic or hazardous materials involved in the operation of wind farms are relatively small amounts of lubricating oils, hydraulic fluids and insulating fluids. Therefore public health or safety concerns through contamination of surface or ground water or soil is highly unlikely. Personal safety risk to workers from these oils and fluids can be easily managed through the use of well understood handling practices.

HEALTH HAZARDS FROM ELECTROMAGNETIC RADIATION AND ELECTROMAGNETIC FIELDS

Like all electrical generating facilities, wind generators produce electric and magnetic fields. The level of risk from wind farms in this regard is extremely low. This topic is covered in more detail in Australian Wind Farms – Electromagnetic Compatibility and Electromagnetic Fields.

WIND TURBINE GENERATOR FAILURES

Properly designed, constructed and maintained wind turbines are safe. Most wind turbines currently available for purchase internationally meet international engineering design and manufacturing safety standards. Here in Australia there are significant financial incentives to ensure that equipment meets very high safety standards. Apart from the various design and construction standards and workplace safety laws, it is not possible that an operator of a wind farm will be able to obtain even basic insurance for the wind farm unless such compliance can be proven.

The international standards cover tower, blade and generator design. There is an international quality control assurance programme for turbines, and a number of relevant standards. In addition, foundation design and commissioning checks address potential failure due to extreme events such as earthquakes or extreme wind loadings, as well as frequency tuning of the different parts of the structure to avoid failure due to dynamic resonance.

International experience to date has indicated very low risks associated with tower collapse, components falling from towers, and blade throw. Risks appear to be reducing further as technology improves. Publications such as Wind Power Monthly and Wind Stats provide current information on industrial accidents and failures of components.

BLADE FAILURE

While there have been rare cases of turbine blade damage in exceptionally high wind conditions (discussed below) – the overall risk to public safety is extremely low. There is a remote chance of a damaged rotor blade being thrown from a wind turbine, or of ice flying from the blade in extremely cold conditions.

The wind farm should be designed and sited such that no buildings or populated areas lie within the possible trajectory range of the blade. This range can vary with the size, shape weight and speed of the rotor and the turbine height, but is unlikely to exceed 300 metres. The risk of being hit by turbines, turbines parts, or ice fragments, within a distance of 210 metres, is 1:10,000,000, comparable to the chance of being hit by lightning (Taylor and Rand, 1991).

The minimum desirable distance between wind turbines and occupied buildings, calculated on the basis of visual impact and expected noise levels, will always be greater than that necessary to meet safety requirements.

Routine Detailed Inspection of Blades

BLADE ICING

Among the cases considered in the design of modern wind turbine generators, one deals with icing of the fibre glass blades. As no standard exists regarding this aspect, the certification agency - Germanischer Lloyd - has worked out a load case, where the entire rotor is covered with a 40 mm layer of ice. The dynamic load influence of this is considered during operation.

As for the safety aspects of icing of the structure and the blades, experience has shown that ice will only build up on the rotor when it is not rotating. This is due to the flexible nature of the blades, which prevents ice from attaching to the surface during their normal rotation.

In the unlikely event that ice should actually cover the rotor, it will seriously affect the aerodynamic properties of the rotor blades. Consequently it will rotate very slowly, if at all, with ice covering the blades.

In the event where ice has covered a stand still rotor and the wind increases to a point where rotation is possible, the blade flexing will cause the ice to break off and fall vertically to the ground before significant speed has been achieved.

Actual "sling shooting" of ice has never been reported.

In cases where the wind turbine tower, nacelle or blades are covered in ice, it will naturally be hazardous to pass and stay directly under the turbine. In this aspect wind turbines are no more of concern than any other building in such environments.

Modern wind turbine generators that are equipped with highly sensitive vibrations sensors that can react swiftly to any imbalance that may indicate a build up of ice on the rotor.

LIGHTNING STRIKE RISK

Modern turbines are equipped with an extensive lightning protection system that transfers high voltages and currents without affecting turbine operations. If a wind turbine is struck by lightning, the lightning will always take the route with the best conductivity - i.e. the least resistance.

Most modern turbines are equipped with total lightning protection in the form of a special ‘lightning route’ through the turbine. Lightning is led from the tip of the blade, down to the blade hub from where it is led through the nacelle and the tower down to the ground. This is very simple and extremely effective.

Generally speaking, wind turbines are not often struck by lightning. However the taller the turbine tower, the greater the chance of it happening; and some areas are more prone to lightning strike than others (a function of weather patterns). No matter how effectively a turbine is protected, it is impossible to completely eliminate the risk of a wind turbine being struck.

Therefore, it is not a question of avoiding lightning, but more a question of controlling and conducting it through the turbine and tower construction – and thus minimise possible damage to the turbine, and therefore, risk of fire as a result of lightning strike.

Extensive testing and refinement of lightning protection systems is conducted at a number of facilities around the world, including full scale testing facilities.

Figure 6 Full Scale Testing of Blade Lightning Protection

CASE STUDIES OF TOWER FAILURE

All modern turbine control systems require complete shut down during excessive wind speeds, reducing the risk of the turbine or tower failing. However there have been rare occasions when catastrophic failure of the wind turbine has occurred.

HAVÖYGAVLEN, NORWAY (OCTOBER 29 2002)

On Tuesday afternoon (October 29), one of the Nordex wind turbines installed in Norway was damaged. At around 5:00 pm in the afternoon, the nacelle including the rotor was severed from the tower. Prior to this, the rotor had been turning at an excessively high speed as a result of an incorrect manual adjustment to the turbine control system. The turbine had only recently been put into operation.

The detailed control log reveals that at the time of the accident the turbine was operating at 44 rpm (tip-speed 663 km/h). Under normal operating conditions, a maximum of only 19 rpm (tip-speed 289 km/h) is permitted. This high turbine speed exerted extreme strain on the turbine, ultimately causing the incident. According to Nordex, the wind speed at the time of the accident was up to 15 m/s, normally an uncritical speed for this turbine.

On the basis of investigations made so far, the accident was caused by incorrect intervention in the controlling system. The turbine had signalled that the rechargeable batteries supplying the rotor brake (pitch drives) in the event of a power failure were not sufficiently charged. In order to start the turbine, an automatic safety-system, which would normally have prevented operation of the turbine with this defect, was deactivated. During the following operation, there was a failure in the normal power supply, with the result that the turbine turned at an uncontrolled speed.

Further investigations have been initiated to determine how an unauthorized deactivation of critical functions of the safety system could occur. Nordex stresses that this incident was a one-off occurrence which has nothing to do with the turbine technology used.

No-one was hurt and nor was there any further damage to property as a result of the accident.

Occupational Health and Safety Aspects of Wind Farm Management

Policies protecting health and safety on a wind farm are an important part of the overall management strategy. A poor health and safety record not only costs a company a great deal of money, but also causes a loss of reputation. Health and safety issues must be considered at all stages of a wind farm development and the risks to employees, contractors and the public assessed and action taken to avoid accidents.

The occupational safety hazards of wind energy are readily apparent – high wind speeds, heights, rotating machinery and the large spinning mass of the wind turbine rotor. "There are no latent diseases, no black lung, no radiation-induced cancers. When wind kills, it does so directly and with gruesome effect" … Since the early 1970's wind energy has killed 14 men worldwide directly or indirectly and seriously injured or crippled three men and one woman… most have died during construction or construction related accidents" [10].

Most currently constructed wind turbines are made in such a way, that dangerous climbing is eliminated during routine operation (inside stair access to nacelle of large turbines, etc.) However, during construction and repair, hazards may still exist. They are of a nature common to most structures (tall buildings, masts for overhead transmission lines, and so on). Therefore the nature of the hazards is well-known, and measures to reduce the risk below given standards are generally known[11].

All of the deaths so far in the wind energy industry were preventable by what is today seen as "common sense industry practice". The use of modern travel restraint systems and fall arrest systems together with personal safety protection equipment to protect the head, eyes, hands and feet has gone a long way in managing the risk associated with wind turbines. Proper procedures also play an important role. Today the turbines are shut down before personnel climb the towers and the rotor is locked in place once they reach the nacelle. This is because in the past operators have been killed when their safety lanyards became entangled in rotating machinery while they were in the nacelle.

While the personal risk associated with wind energy is now very low, safety continues to be an issue for all associated with the industry, as constant vigilance is our best defence.

Health and safety must be taken as part of the overall management strategy, with strong guidelines for safe working practises.

The Risks

Although wind power has few risks of industrial disease from hazardous substances the risks faced by employees are significant.

- Working at height
- Rotating machinery
- Heavy machinery
- High voltage electricity
- Hazardous weather conditions
- Vehicle access

[10] Wind Energy Comes of Age. Paul Gipe John Wiley & Sons1995 ISBN 0-471-10924-X. pp364
[11] "Renewable Resources and the Environment – Wind Energy" Prof. Bent Sørensen Roskilde University

A good safety regime can reduce these risks greatly. One of the main issues is for employees to take responsibility for their own safety. When in contact with risk on a daily basis, the temptation to take short cuts can be strong. Indeed many industrial accidents are due to employees ignoring guidelines. Constant reminders of the dangers and the need for good working practise must be reinforced.

Other risks to both employees, neighbours and the public need to be assessed. These risks may range from improbable events, such as a blade throw to more mundane risks such as tripping hazards. The presence of high voltage electricity, of course, is also a major risk. Management need to consider access to the land, signposting and warning notices. Accidents may still happen, but the impact may be significantly lessened.

Risk Assessment

It will not be possible to completely eradicate all accidents, but the risk assessment should allow the management to assess the level of acceptable risk. The hazards at each stage may need to be rated according to the likely severity of injury. Some hazards may be extremely unlikely, but may have very severe consequences. In this case the management may decide that any risk is unacceptable.

At each stage of the development and operation of a wind farm, or a single turbine, the risks to all who may be on the site must be assessed. For each stage the hazards should be identified, those at risk should be noted and how they might be harmed. Any existing control measures should be noted and if these do not fully control the risks that have been identified, further control measures need to be designed. The assessment should then be reviewed at regular intervals.

When work is being carried out in remote areas good communication links between weather stations, base stations and on-site personnel are required to enable speedy evacuation should there be an adverse change in the on site conditions.

If there is the possibility of personnel being marooned at a turbine overnight due to poor weather conditions, suitable sleeping accommodation may have to be provided. Such accommodation will need to include shelter, heating, emergency power and supplies of food and drinking water.

Emergency Response

The response to any accident or emergency situation needs to be thoroughly researched, carefully planned and well understood by all personnel on site. The remoteness of wind farm sites and the potential risk factors that may contribute to serious injury will usually mean that emergency response plans will need to be developed in consultation with emergency services (e.g. ambulance, fire, SES and police).

When an accident or emergency situation occurs on a wind farm site, the first response needs to be able to cope with the worst circumstances, unless the situation clearly requires only a lower level or response. This is not unusual to the wind industry. Even a small fire at a chemical storage facility will illicit an aggressive response from fire fighting services until it is clearly established that the situation can be brought under control with a lesser response team.

On a wind farm site, if a worker suffers a crushing or falling injury (even if seemingly minor) an aggressive response (e.g. call out of air ambulance) will be immediately initiated. This approach can (and has) lead to “false alarms”, where in hind sight a lesser response may have been adequate. However the potential for the patient’s condition to deteriorate rapidly (e.g. due to “suspension syndrome” or internal injuries that may not be readily apparent to first aiders) means that it is better to have the best services on the way to site as quickly as possible so the patient can be evacuated to qualified personnel rather than find out too late that on-site facilities are inadequate.

While the calling of a rescue helicopter to a rural construction site may create some overly excited responses from the local press and generate a lot of paperwork for management, the rapid and decisive implementation of pre-arranged emergency response plans has a very real potential to save lives.

OFF SHORE WIND FARM SAFETY

The things that make offshore wind energy so attractive - powerful winds, being situated far from land – are also what make offshore wind farms so challenging and potentially dangerous to the people who have to install and maintain them. Both the machines and the people who work with them are specially modified for offshore operations.

While we are unlikely to see off-shore wind farms for some time here in Australia it is important that we keep abreast of these developments. Many of the wind farms here in Australia will be in very remote locations and technicians will face many similar issues to those experienced at off-shore wind farms in other parts of the world.

Special off-shore wind turbine safety courses are now conducted to ensure all employees are properly trained prior to going off-shore. Participants in these offshore safety courses are trained in everything from basic maritime skills to handling fires and being hauled up or down from a helicopter. They learn how to moor a vessel to a stationary platform - something that can be much more challenging than it sounds, especially in the rough North Sea.

So far all the off-shore wind farms have been located in areas with very cold water temperatures. Special survival suits need to be worn in case of immersion. They are padded with air and foam to keep people warm and afloat. With these survival suits it is possible to actually survive in freezing water for up to a whole day. Survival suits such as these are now standard gear for all offshore employees. An important aspect of the training is to learn how to treat people suffering from hypothermia, i.e. the severe cold shock that comes from falling into cold water without a survival suit.

The training course is very practical and includes many real life exercises such as being thrown overboard and rescued by the other participants. As is the case in real life, participants carry out the exercises in all kinds of weather, be it rain, storm or snow.

There are special requirements for offshore turbines, especially in the area of servicing. To meet these requirements special modifications are made compared to their land-bound counterparts. For example the V80-2.0 MW turbines installed at Horns Rev have a heli-hoist platform (a special platform) has been built on the back of the nacelle so service people can be hoisted down to the turbines from helicopters. And to reduce the need to transport tools back and forth to the turbines, there are tools and other repair facilities inside the nacelle.

In addition, the turbines are supplied with special emergency features such as rations (enough for several days) and hammocks if the service technicians suddenly have to stay overnight because of unexpected bad weather. Plus other emergency equipment such as fire extinguishers, survival suits (which the technicians wear out to the turbines), life jackets, radio equipment and more.

In addition to the special measures taken in regard to the safety of the service technicians and to servicing the turbines, the turbines are also equipped with both aviation and navigational warning lights and fog horns to warn approaching ships and airplanes.